

The Occurrence of Diet Items in Coastal Cutthroat Trout Collected in South Puget Sound, 1999-2002

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Abstract

This study explored coastal cutthroat predation of salmon eggs and fry, and the ecological implications of this behavior.

From July 1999 to April 2002, 115 coastal cutthroat were captured by catch-and-release angling in South Puget Sound. Ninety-four stomach samples were analyzed. Wet weights of diet items were salmon eggs and chum salmon (*Oncorhynchus keta*) fry (46%), other non-salmon fishes (23%) and polychaetes (12%). Invertebrates (amphipods, isopods, shrimp and clam necks) constituted 17%, and other items 2%. The most important non-salmon fishes in the diet were shiner perch (*Cymatogaster aggregata*), Pacific herring (*Clupea harengus pallasii*), Pacific sand lance (*Ammodytes hexapterus*) and arrow goby (*Clevelandia ios*). Cutthroat length when salmon were present and not present, was not significantly different (Chi-square = 0.11, 2 df). Apparently, coastal cutthroat preferentially select salmon eggs and chum salmon fry when they are present, despite the abundance of alternative food items, and shift to these alternative items at other times.

Increased fitness and fecundity of coastal cutthroat is likely the result of successful life history traits, such as interspecies feeding. Setting ecologically based escapement goals for Pacific salmon could support coastal cutthroat population growth.

Introduction

One aspect of juvenile salmonid development in estuaries that is presently not well understood is interspecies interactions, such as predator-prey relationships. Of particular interest here is the extent to which coastal cutthroat (*Oncorhynchus clarki clarki*) prey upon young salmon, and the ecological implications for salmon and cutthroat that may follow from current management policies. Prey abundance may influence the distribution and survival of coastal cutthroat in estuaries and near-shore marine waters, although little is known about the complexity of interactions between coastal cutthroat and other Pacific Northwest salmon (*Oncorhynchus* spp.). Relatively little research has been done on coastal cutthroat diet in Puget Sound, and although estuary diet studies were done in the Columbia River and other states (Giger 1972b; Armstrong 1971; Loch and Miller 1988; Pearcy 1997).

Despite being found in many Puget Sound streams and rivers, the lack of data on coastal cutthroat has probably occurred because cutthroat populations are dispersed or their lack of value as a commercially exploited species (Trotter 1997; Raymond 1996). Cutthroat are vulnerable to recreational over-fishing and commercial fisheries by-catch because they are highly accessible during their residence in marine nearshore areas (Giger 1972a, 1972b; Behnke 1992; Emmett et al 1991; Trotter 1987; Wydoski and Whitney 1979). Salmon managers could use coastal cutthroat diet data to improve management of all Pacific salmon because a direct nutritive relationship has been found, in rivers, between salmon runs and subsequent salmon production (Michael 1995).

Recently, in Southwest Washington and the lower Columbia River Evolutionarily Significant Unit, coastal cutthroat were proposed for threatened status under the Endangered Species Act (ESA), and a decision was made not to list the species (USFWS 2002). The decision was based on field surveys that showed small, widely distributed populations of resident stream-dwelling cutthroat, that were genetically similar to coastal cutthroat, thus providing a stable contribution to anadromous populations. Coastal cutthroat will probably be of increased management concern in the future, because the species faces many problems similar to ESA-listed salmon species (Brown and Craig 2002; Nehlson et al. 1991).

Unlike other Pacific salmon, coastal cutthroat usually do not migrate far offshore in the Pacific Ocean, mostly living within a few kilometers of shorelines and migrating to the upper-most, high gradient reaches of small freshwater streams for spawning (Johnston 1982; Trotter 1997; Garrett, A. 1998). Anadromous cutthroat, feeding in salt water and returning to spawn in fresh water, can migrate between fresh and marine waters before maturity to feed, and after maturity to feed and spawn (Garrett, A. 1998). Thus cutthroat sub-adults and adults in estuaries probably have seasonal feeding opportunities on the eggs, carcass flesh, fry, and smolts of other Pacific salmon, such as the abundant chum salmon (*O. keta*). The abundance of the other six species of Pacific Northwest salmon may be an important dietary influence on

coastal cutthroat populations, and reciprocally, coastal cutthroat predation may impact Pacific salmon. Investigation of coastal cutthroat interaction with other salmon could provide evidence of the interspecies effects that declines of other salmon populations may have on the abundance of coastal cutthroat (Cederholm 1998).

The objectives of this study were to:

- (1) Measure relative abundance of prey in coastal cutthroat diet in estuaries.
- (2) Document coastal cutthroat predation or scavenging of Pacific salmon.
- (3) Clarify the ecology of coastal cutthroat interspecific behavior in estuaries.

Ecology of Salmon in Estuaries

The zone of transition between the Pacific Ocean and the coastal temperate rain forest has been called a terrestrial-marine “ecotone,” an area characterized by a multitude of energy convergences and discharges of water, sediments, organic matter, nutrients and debris (Simenstad et al. 1997). At the interface of tidal fresh water and brackish water, salmon smolts must osmoregulate, find new forms of prey, and avoid predators (Healey 1982).

The interactions between organisms and their physical and ecological habitats may determine the productive capacity and population composition of Pacific salmon (Simenstad et al. 2000). Many prey species of juvenile salmon originate in the land/sea margin of the salt marshes and eelgrass beds of estuaries (Simenstad et al. 2000). In freshwater tidal habitats, complexes of sloughs, dendritic channels, marshes, swamps, and forests efficiently collect organic matter, provide primary estuary food web production, and are especially important as rearing and overwintering areas for coastal cutthroat trout (Simenstad et al. 1997).

Dietary differences among juvenile salmon in the ecotone suggest evolutionary “partitioning” of the available prey species (Simenstad et al. 2000). Most small juvenile salmon (30-60 mm) use shallow-water tidal areas extensively for migration, feeding, and refuge (Cederholm et al. 2000). Six of the seven species of Pacific Northwest salmon, pink (*O. gorbuscha*), chum (*O. keta*), coho (*O. kisutch*), sockeye (*O. nerka*), chinook (*O. tshawytscha*) and steelhead (*O. mykiss*), rely on safe passage through estuaries in the smolt stage (Groot and Margolis 1991). After occupying estuary habitats for varying periods as smolts, they continue their outward migration to the open ocean to begin their adult lives, and eventually migrate inward to freshwater as returning adults to spawn.

In contrast, following a relatively long early life history in fresh water, sub-adult and adult coastal cutthroat primarily prefer estuary and nearshore habitats (Trotter 1997). Cutthroat do not usually migrate far offshore, preferring to stay close to their natal stream, making estuaries important, if not key, habitats for coastal cutthroat (Trotter 1989; Johnston 1982). Thus, for coastal cutthroat, estuary food and habitat resources may be more decisive in maintaining healthy populations than for other Pacific salmon species.

This lengthy residency may make coastal cutthroat more susceptible than other Pacific salmon species to human impacts on estuary areas, such as fishing, urbanization, industry, diking and dams. Most Pacific Northwest estuaries have been drastically changed since Europeans settled western North America. In Puget Sound, 42% of the coastal tidal wetlands, 71% of the estuaries, and 70% of the eelgrass have been reported as lost (Simenstad and Thom 1992). The abundance and distribution of cutthroat could serve as a biological indicator for key salmon estuary ecosystem functions (Behnke 1987).

Coastal Cutthroat Life History:

Anadromous cutthroat develop as juveniles in fresh water for two to seven years, migrate to estuaries where many live for varying portions of their lives, returning to freshwater for annual feeding runs and for spawning, most often at age three to five (Trotter 1997; Johnston 1982).

“Amphidromous” cutthroat migrate between fresh water and sea water not exclusively for breeding but also regularly at some other stage of the life cycle; sexually immature cutthroat may return to freshwater once or twice, with many not reaching sexual maturity until spending another year at sea (Trotter 1989; Garrett, A. 1998). They prefer to concentrate in bays, estuaries and along the coast, where they can grow up to 25 mm per month (Behnke 1992). In view of their predatory nature and long maximum life span (i.e. 10 years), Behnke (1992) commented that it was unusual that coastal cutthroat of 8-9 kg or more were unknown. The sport-caught Washington state record coastal cutthroat is reported as a 2.7 kg fish, 615.9 mm long, caught in Carr Inlet in May 1943 (Byrd, WDFW, pers. comm. 2002).

Puget Sound cutthroat smolts generally migrate to seawater at age two or three, and to coastal marine waters at age three to five, with migration in Washington and Oregon starting in March and peaking in mid-May (Giger 1972a; Lowry

1965; (Wydoski and Whitney 1979 Michael 1989; Trotter 1989). In Hammersley Inlet, 68% of Mill Creek smolts from migrated to saltwater at age two and 32% at age three (Peoples et al. 1988). The Mill Creek smolt migration spanned April 15 to May 12 and peaked on April 21 (Peoples et al. 1988). Two-year-old Mill Creek smolts were 140-204 mm fork length, averaging 175 mm, and three year olds ranged from 186-234 mm, averaging 206 mm (Peoples et al. 1988).

Coastal cutthroat smolts form schools just before saltwater entry that remain intact until they return to freshwater (Giger 1972a, 1972b; Trotter 1989). Schools of 5-15 sub-adult cutthroat forage opportunistically off gravel beaches, oyster beds and eelgrass on a variety of small fish and invertebrates. In the spring, in estuaries and lower tidal reaches of some rivers, cutthroat are known to feed on outmigrating trout and salmon fry (Trotter 1987). Most estuaries probably have some coastal cutthroat present at all times (Hunter, WDFW, pers. comm. 2001).

Substantial movements of adult cutthroat have been reported in fresh water or, with the tide, in and out of narrow estuary areas starting in August (Royal 1972; Trotter 1987). Adult Puget Sound, cutthroat move up Minter Creek and enter a weir trap a few hundred feet above high tide in December in their upstream spawning migration (Royal 1972). Puget Sound adults return to streams from October to January, typically migrating upstream from the first week of October through February, peaking in November (Wydoski and Whitney 1979; Sumner 1962). In Washington, spawning occurs from December through May, peaking in February, and as late as April or May in Alaska (Johnston 1982; Trotter 1989).

Maturing cutthroat have also been observed in the estuaries and lower river areas of most coastal streams during late summer, often as early as July. At Snow Creek, Washington, two cutthroat run times have been described, a late entry stock (winter and spring) generally associated with small drainages, as contrasted with early entering stocks (August) in large river systems (Michael 1989).

From October 1986 to March 1987 in Eld Inlet (my study area), 79% of adult cutthroat sampled from McLane Creek were age two and 18% were age three, by scale analysis (Peoples et al. 1988). Mature females in McLane Creek were 285 to 572 mm fork length, averaging 432 mm, while immature females were 229 to 338 mm, averaging 293 mm; mature males ranged 248 to 458 mm, averaging 335 mm (Peoples et al. 1988). In October only immature female cutthroat and small mature male cutthroat were captured, and on November 13, large mature females were first captured (Peoples et al. 1988). From January 15-19 entry of mature females peaked, and spent females were observed from January 15 to February 26 (Peoples et al. 1988). Mature cutthroat were captured until February 26 and a significant decrease in migrants was observed after that (Peoples et al. 1988).

The spawning migration in Minter Creek starts in December and ends in early April, peaking January to March (Royal 1972). In November 1986 to January 1987, Minter Creek mature female cutthroat were 273 to 533 mm fork length, averaging 400 mm, while mature males were 267 to 470 mm, averaging 357 mm (Peoples et al. 1988). In Minter and McLane Creeks, 30% of the mature males and females had returned to freshwater at least three times; some McLane Creek individuals had returned up to five times (Peoples et al. 1988).

In Washington, return of spawned out adult cutthroat to saltwater peaks in late March to early April, cutthroat smolts downstream migration peaks about a month later, and this cutthroat movement precedes the peak downstream migration of fall-spawned pink and chum salmon fry (Trotter 1989). However, fry from the (few) earlier spawning summer chum salmon migrate in January to March (Michael, pers. comm. 2002). Natural selection has probably favored this timing because it positions the cutthroat kelts to intercept schools of pink and chum salmon fry in estuaries (Johnston 1982; Trotter 1989; Giger 1972a).

Small differences in cutthroat life history are not detected by genetic analysis, although they have a hereditary basis and are adaptive (Behnke 1997). Cutthroat adaptation to freshwater entrance and proximity to nearshore waters could allow opportunistic feeding on the smolts of other salmon, and is especially likely for cutthroat where abundant out-migrations of chum and pink salmon smolts occur (Johnston 1982; Trotter 1989; Wydoski and Whitney 1979). Cutthroat movement to nearshore areas probably confers a selective advantage, by reducing time spent in fresh water for reproduction and early rearing, allowing larger fish to seek habitats where food resources are more abundant and available (Northcote 1997, Johnson et al. 1999). Salt water feeding can increase size and fecundity, but exposes cutthroat to risks of high energy demands, stress during osmoregulation, predation, parasites, competitors, and eventually the migratory exposure while locating suitable freshwater spawning habitat (Northcote 1997; Palmisano 1997).

Estuary Feeding and Prey of Coastal Cutthroat

The nearshore diet of coastal cutthroat consists of a wide variety of small marine fish, invertebrates and terrestrial insects, indicating that the highly predaceous cutthroat are opportunistic feeders (Wydoski and Whitney 1979; Behnke 1992). Some nearshore food items are amphipods, isopods, shrimp, small fish including stickleback, sand lance, and sculpins, and in the spring, outmigrating juvenile salmon (Wydoski and Whitney 1979; Trotter 1987). Cutthroat kelts' size confers a predatory advantage over outmigrating salmon juveniles, allowing cutthroat to prey on them in freshwater and estuaries (Pearcy et al. 1990).

The importance of the nearshore to coastal cutthroat may vary across large geographic areas, depending on conditions (Reeves et al. 1997). Close proximity to fresh water can provide important opportunities for cutthroat growth and dispersal to neighboring drainages (Johnson et al. 1999). Entry and exit for freshwater refuge and feeding gives them opportunistic access to seasonal food sources, such as insects, salmon eggs, carcass material, fry or juveniles. Cutthroat have been called "opportunistic feeders" because they have been observed in fresh or saltwater locations with the most abundant, high quality food at the time (Simenstad et al. 1982; Fresh et al. 1981; Fresh and Schroder 1987). Freshwater re-entry for spawning, feeding, or refuge, places cutthroat in and near salmon spawning streams in the fall, when salmon eggs and carcass flesh are available (Johnston 1982; Trotter 1989; Raymond 1996).

Cutthroat predation of juvenile salmon in freshwater can be significant under some conditions, although Simenstad et al. (1982) found relatively few juvenile salmon in cutthroat stomachs in freshwater. Fransen et al. (1993) found age one and older cutthroat in freshwater fed on coho fry until the fry grew too large to capture, and an experimental sample of 31 cutthroat in lower Big Beef Creek averaged three chum salmon fry in each stomach. In Oregon's Kilchis River, an important spawning stream for chum, the stomachs of large cutthroat caught in the spring were full of chum salmon fry; in the Nestucca and Wilson Rivers, with fewer chum salmon, cutthroat consumption of fish was reduced, consisting mostly of aquatic and terrestrial insects (Sumner 1972).

Cutthroat feed on drifting eggs displaced by upstream salmon spawning activities, such as in Oregon's Sand Creek, where "trout" consumed chum salmon eggs dug up by spawning chums (Sumner 1953). A coastal cutthroat was observed actively feeding on drifting, displaced chum salmon eggs in 1998 in Fiscus Creek, a tributary of Kennedy Creek, which enters the Totten Inlet study area. (Pittman, WDFW, pers. comm. 2000). In the intertidal area of Kennedy Creek, a cutthroat was observed aggressively "bumping the chum hens" (females) by driving its nose into the side of the female chum to force the release of eggs, and to immediately "scoop up the eggs and repeat the process," several times (Dickason, Squaxin Tribal Fisheries, pers. comm. 1998).

Aggressive fall feeding by cutthroat has not been consistently observed, such as in Oregon, where tagged adult cutthroat entering the Alsea River estuary had stopped feeding, and recaptured fish had lost weight (Giger 1972b). An alternative explanation is that these cutthroat were feeding but were not getting enough food to produce a weight gain (Michael Jr., pers. comm. 2002). Downstream Alsea River migrant cutthroat fed on sand shrimp and various small fish, but salmon fry were not noted in their diets (Giger 1972a, 1972b).

Significant cutthroat predation of salmon in nearshore Washington waters is lacking or inconsistent (Simenstad et al. 1982; Groot and Margolis 1991). Cutthroat would probably feed heavily in salt water if abundant chum salmon fry were present. Juvenile chum and pink salmon use shallow sublittoral areas, and eelgrass, especially in contained embayments for 6-23 weeks in Washington, making them very available as coastal cutthroat prey (Simenstad et al. 1982).

Food abundance could determine the habitat distribution of coastal cutthroat in nearshore waters (Meyer 1979). Assuming that plentiful nearshore food resources are sufficient to offset the survival risks to cutthroat, their regular movement between feeding, wintering, and spawning habitats responds to environmental variability and, in the case of prey, might be a response to resource predictability (Northcote 1997). The adaptive significance of a population partitioned into a broad migratory/resident spectrum has been characterized a species' "bet hedging" for long term continuity (Northcote 1997).

Cutthroat have been infrequently caught by beach and purse seining, perhaps because of their ability to easily escape capture (Fresh et al. 1979; Meyer et al. 1981). The few seine captures of cutthroat report differences in the selection of salmon juveniles (Simenstad and Eggers 1981; Meyer et al. 1981; Pearce et al. 1982). Six cutthroat seined at the Nisqually Reach in 1977-78 had consumed two (probable) salmon fry, the only significant fish predation among all salmon captured (Fresh et al. 1979). Of nine cutthroat seined at the Duwamish Estuary in April-July 1980, one had preyed on four juvenile fish, however none were identified as salmon (Meyer et al. 1981).

In an Alaska wilderness area, 83 coastal cutthroat captured at the outlet of Eva Lake in July-August 1964, had “fed heavily” on sockeye fry, coho fry and fingerlings and insects; thirty-five percent had eaten young salmon (Armstrong 1971). Twelve nearshore cutthroat (average length=240 mm, range 203-270 mm) also captured at that time had fed on amphipods, pink and chum salmon fry, prey items found primarily in shallow water habitats (Armstrong 1971).

In the Columbia River estuary, Loch (1982) found the American shad was the most numerous prey species of 67 cutthroat taken August through September, when migrating salmon smolts would have been larger in size and less numerous. Chum and pink salmon fry were not prevalent in the Columbia River, presumably due to their depressed or extinct stock conditions (Michael Jr., WDFW, pers. comm. 1999). Another Columbia River estuary sample of 11 cutthroat taken April through June found amphipods (*Corophium salmonis*) and adult insects were the most important prey (Bottom et al. 1984). Offshore of the Columbia River, Loch and Miller (1988) found no cutthroat predation of salmon when large numbers of juvenile chinook and coho were present, and Pearcy (1997) reported that coastal cutthroat mainly preyed on small non-salmon fishes and occasional juvenile salmon.

In Puget Sound’s Nisqually reach, approximately half of 23 coastal cutthroat sampled in April 1979, contained chum salmon juveniles (Fresh et al. 1981). In a Hood Canal study, salmon fry constituted 11% of cutthroat prey, and Trotter (1997) commented that cutthroat predation of juvenile salmon is probably situational, based on opportunity during high-density fry migrations. A reviewer notes that some smolt and adult cutthroat live in estuaries and feed mainly on out-migrating salmon fry (Atkin 1998). Another reviewer commented that Puget Sound cutthroat stay close to their natal rivers, that juveniles feed on insects, crustaceans and some fish, “...while subadults and adults are highly piscivorous in the marine estuaries and fresh waters” (Cook-Tabor 1999, p 11).

The inconsistent observations of cutthroat predation of salmon fry are probably primarily due to human-caused degradations throughout terrestrial and aquatic systems (Michael Jr., WDFW, pers. comm. 2000). The following characteristics of coastal cutthroat seem consistent.

1. **Opportunistic-** Coastal cutthroat frequently consume pink and chum salmon fry, when fry are available, especially *en-masse*, in fresh and salt water.
2. **Predator size** is a more important than prey size, since larger cutthroat had greater predation rates on salmon fry.
3. **Life history advantages** of freshwater feeding runs, iteroparous spring spawning allows coastal cutthroat age 1+ and older seasonal feeding opportunities on chum salmon eggs, carcass flesh and fry.
4. **Survival advantages** of increased fecundity and fitness could be significant for coastal cutthroat with reference to the “niche feeders” of Johnston (1982) and the “bet hedging” of Northcote (1997).
5. **Complex interspecies interactions and dependencies** in salmon ecosystems probably shape coastal cutthroat life history (Johnston 1982; Cederholm 1998).

Methods

This cooperative project with Washington Department of Fish and Wildlife (WDFW), investigated the interspecies feeding by coastal cutthroat on salmon, especially the abundant fall chum, in four South Puget Sound inlets (Eld, Totten, Skookum, and Hammersley Inlets, Figure 1), between 24 July 1999 and 8 April 2002. WDFW permitted fly anglers to capture, sample and release coastal cutthroat with single barbless-hook artificial flies, from small boats and beaches. Angling was selected as the method of sampling because of the relative lack of success of beach seining for this species (Fresh et al. 1979; Simenstad et al. 1981; Meyer et al. 1981).

Sampling sites were chosen for the availability of reasonable access, angler knowledge of coastal cutthroat habitat, time available to fish, fishing opportunity, major tide cycles, low light conditions, and barometric stability. Sampling occurred in all months, and was purposive regarding selections of season, weather, time, location and field conditions.

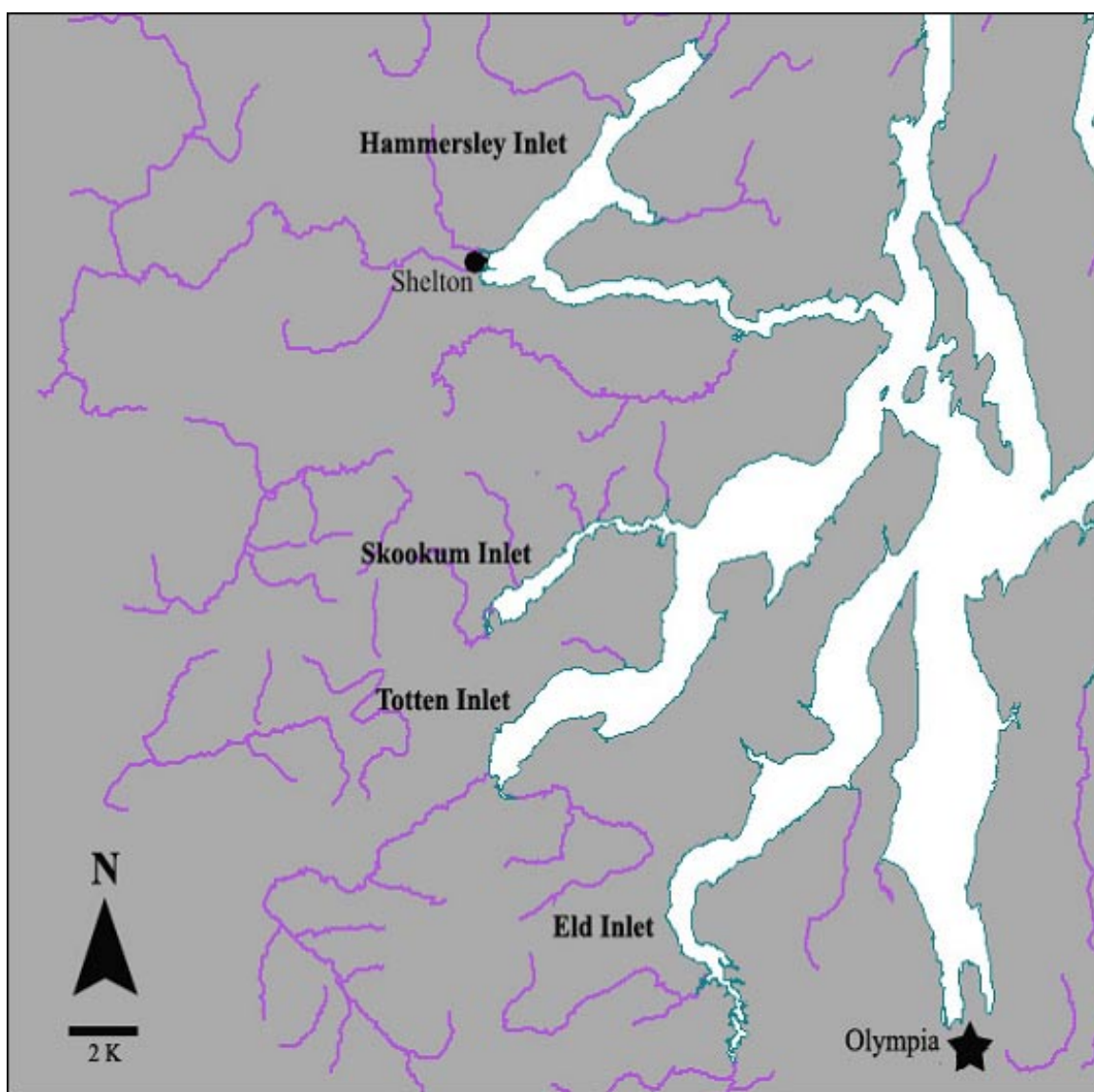


Figure 1. South Puget Sound inlets and salmon-bearing streams.

Beach access in all inlets was limited by private ownership of shoreline residences, and field activity was constrained by occupational and academic schedules.

Cutthroat were handled carefully and rapidly with emphasis on survival. Captured fish were immediately placed in a 5-gallon bucket of seawater and anesthetized with the chemical M.S. 222 (*Tricaine methanesulfonate*), with approximately 0.5 g per two gallons of water (Bell, 1984). Fish were measured (fork length), a scale sample was removed, and stomachs were lavaged with 60cc of seawater to remove contents (Hyslop 1980; Meehan and Miller 1978). Fish were immediately placed in a full 5-gallon bucket of seawater for revival and gently released as soon as they showed vigorous recovery. Scale and stomach samples were put in separate labeled containers and recorded; stomach contents were refrigerated in 99% isopropyl alcohol. With experience, cutthroat were processed from anesthetic to revival in 40-50 seconds or less, and released at the capture location within a few minutes.

Field book recordings included angling effort, any other positively observed, uncaptured coastal cutthroat, and any other fish caught or observed. I also noted any other predators or wildlife (marine, avian or mammal), and biological or ecological features, such as weather and tide conditions, and any other influences on sampling (fishing) conditions.

Samples were analyzed in the laboratories at WDFW and Evergreen State College as follows: sample jars were emptied into a Fischer Scientific Co. sieve of size #35-39, with a mesh opening of 500 microns, rinsed with water, placed in a

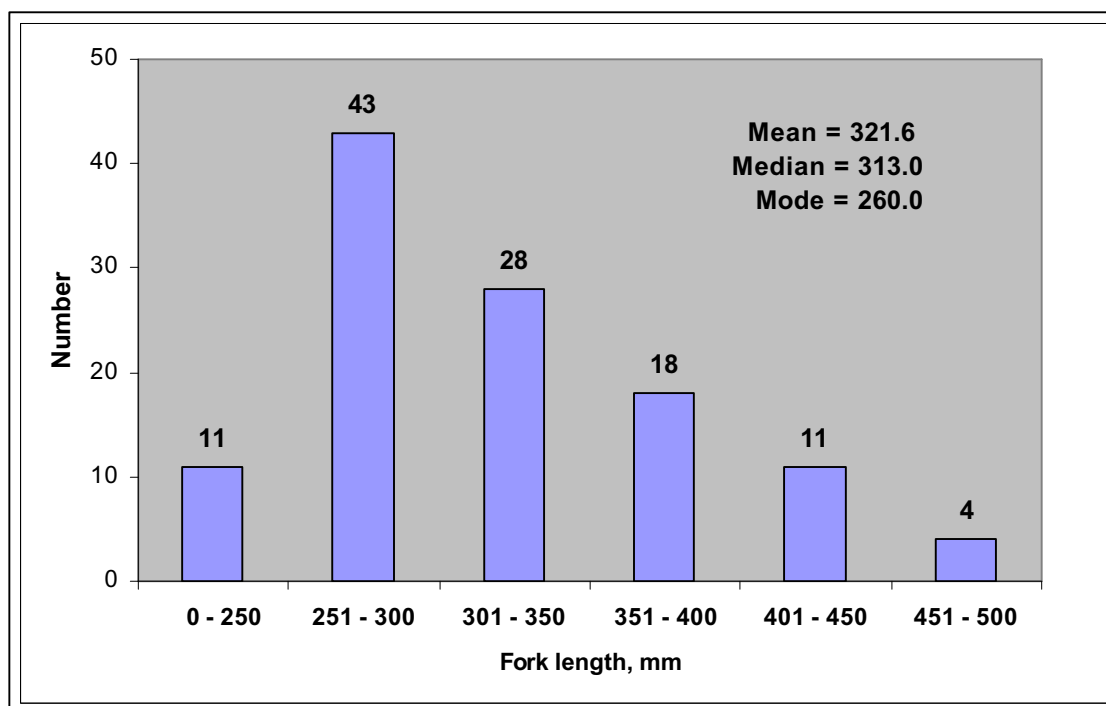


Figure 2. Length frequency distribution for 115 coastal cutthroat collected from South Puget Sound inlets, 1999–2002.

petri dish with water, and observed with a lighted 40x dissecting microscope. Samples were separated into invertebrate, vertebrate, vegetative, and other groups of material, and identified using keys and the help of marine experts (Hart 1973; Garrison and Miller 1982; Fujita 1990; Miller and Lea 1972; Miller et al. 1980; Lamb and Edgell 1986; Harvey et al. 2000). For marine invertebrates the sources were: Butler 1980; Brusca 1980; Gardner and Szabo 1982; Kozlof 1996 and 1993; Smith 1975; Todd et al. 1996. For insect identification the sources were: Bland and Jaques 1978; Borror et al. 1989. Diet items were identified to species (if possible), measured and weighed. Prey fish were identified to species, and invertebrates were identified to order. Wet weight to the nearest 0.001 g was obtained after placing identified prey on absorbent paper towels (Kimberly-Clark Professional WypALL L10 Kimtowels) to remove surface water before weighing on an electronic scale (Mettler BB244 Deltarange) (± 0.001 g).

Samples in advanced states of digestion were taken to the University of Washington, the National Marine Fisheries Service, and WDFW for expert help. Special care was taken to identify prey fishes as salmon or non-salmon with reference collections and keys. Prey data were analyzed by percent frequency of occurrence (%FO), percent numerical composition (%N), and percent contribution to the total weight of prey (%W) (Bowen 1996). Weight and lengths of prey fish items and larger invertebrate prey were recorded, and non-fish items were summarized in higher categories.

Results: The numbers of coastal cutthroat sampled by year were 13 in 1999, 11 in 2000, 39 in 2001 and 52 in 2002; by inlet 38 were sampled in Eld, 22 in Totten, 31 in Skookum and 24 in Hammersley for a total of 115 cutthroat. The increasing trend in catch is due to increased sampling effort and efficiency.

The 115 cutthroat were 195–485 mm fork length (Figure 2), and 94 (82%) provided observable diet samples for analysis while the remaining 21 (18%) diet samples were discarded because they were in a greater state of digestion. It is likely that they were no different than other items.

Table 1 summarizes cutthroat diet, where F is the number of stomachs that contained the diet item (out of 94), N is the total number of items of that category seen in all stomachs, and W is the total weight (g) of that item seen in all stomachs. By weight, the overall diet of coastal cutthroat trout was dominated by salmon eggs and chum salmon fry (46%), followed by non-salmonid fish (23%), polychaetes (12%), other invertebrates (i.e. amphipods, isopods, shrimp and clam necks) (17%), and other items (2%). In descending order, by weight, the most important non-salmonid fishes in the diet were shiner perch, Pacific herring, Pacific sand lance and arrow goby. The most important invertebrates by weight were gammarid amphipods, shrimp, isopods, and clam necks.

Table 1. Diet items by percent frequency of occurrence (%F), percent number (%N), and percent weight (%W) of coastal cutthroat trout (*Oncorhynchus clarki clarki*) in South Puget Sound, 1999-2002

Diet items	F	%F	N	%N	W (g)	%W
Salmon Eggs	3	0.88%	187	8.13%	25.55	25.63%
Chum Fry	10	2.93%	111	4.83%	20.16	20.23%
Pacific Sand Lance	7	2.05%	8	0.35%	2.88	2.89%
Pacific Herring	3	0.88%	3	0.13%	4.01	4.02%
Three-spine Stickleback	1	0.29%	1	0.04%	0.27	0.27%
Pacific Staghorn Sculpin	3	0.88%	21	0.91%	1.17	1.17%
Arrow Goby	11	3.23%	16	0.70%	2.40	2.40%
Shiner Perch	4	1.17%	5	0.22%	9.19	9.22%
Surf Smelt	1	0.29%	1	0.04%	2.65	2.66%
Unidentified fish	17	4.99%	17	0.74%	0.16	0.16%
Polychaetes	40	11.73%	52	2.26%	12.00	12.04%
Gammarid Amphipods	50	14.66%	555	24.14%	4.81	4.83%
Corophium Amphipods	7	2.05%	27	1.17%	0.11	0.11%
Copepods	6	1.76%	6	0.26%	0.03	0.03%
Isopods	29	8.50%	351	15.27%	2.20	2.21%
"Shrimp"	32	9.38%	73	3.18%	6.68	6.70%
Crabs	10	2.93%	10	0.43%	0.59	0.59%
Barnacle larvae	7	2.05%	18	0.78%	0.04	0.04%
Clam necks	6	1.76%	721	31.36%	2.71	2.72%
Mollusc	8	2.35%	9	0.39%	0.12	0.12%
Insects	3	0.88%	3	0.13%	0.00	0.00%
Unidentified flesh	44	12.90%	44	1.91%	1.25	1.25%
Unidentified bone	14	4.11%	14	0.61%	0.05	0.05%
Vegetative matter	17	4.99%	18	0.78%	0.14	0.14%
Stones	8	2.35%	28	1.22%	0.51	0.51%
Totals	341	100.00%	2299	100.00%	99.68	100.00%

Seven prominent diet items constituted 4% or greater weight, totaling almost 83% of the overall diet (Figure 3). Salmon eggs and chum fry were the most abundant diet items, followed by polychaetes, shiner perch, shrimp, amphipods and Pacific herring. The relative contributions of large and small items are illustrated by the number of shiner perch (5) as compared with the number of amphipods (555).

The large relative size of a few non-salmon prey fish, such as shiner perch (5) and Pacific herring (3), contributed 13.2% by weight, while numerous, relatively small diet items, such as isopods (351) and clam necks (721), were below 4% by weight of the overall diet of coastal cutthroat.

Coastal Cutthroat Diet Variability by Season

The diet data varied based on assumed seasonal availability of salmon eggs and chum salmon fry, and by the size of coastal cutthroat. For analysis of salmon presence by cutthroat size, the sample was separated into fork length intervals by two seasonal periods of salmon presence.

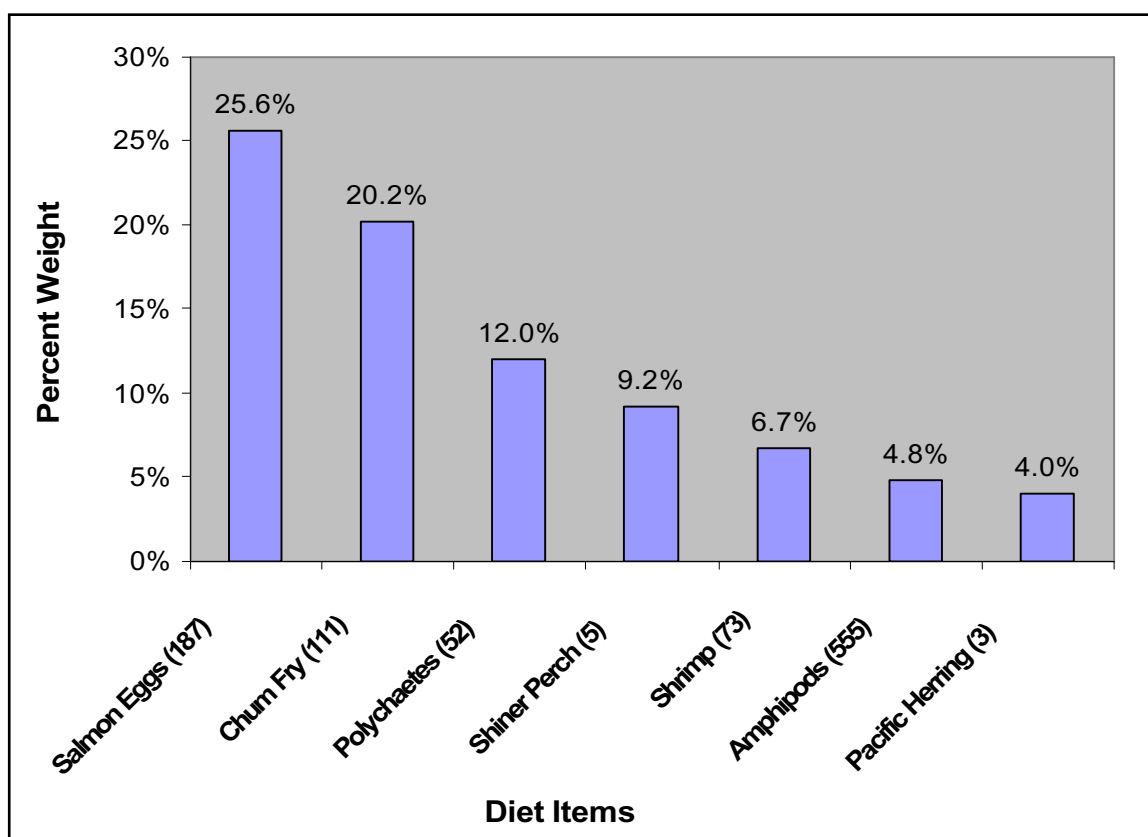


Figure 3. Major diet items of coastal cutthroat trout, from 94 stomachs (82.7% of total diet weight)

The days of sampling when chum salmon were assumed to be present (28), and absent (25), were nearly equivalent, because of deliberate temporal distribution of effort. More cutthroat were captured when salmon were present (69), particularly cutthroat of intermediate size (301-400mm, N=31), and larger (401-485mm, N=11). A Chi-square test was done (Chi Square probability = 0.1103 with 2 df), indicating cutthroat size distribution is not highly significantly different during times when salmon prey are present and absent.

When salmon eggs and fry are present, cutthroat diet items constituting 4% or more of the total weight represents 81% of the overall diet (Figure 4). However, when salmon are not present the diet items constitute 94% of the overall diet. In other words, the cutthroat acquire proportionally less food from a greater number of minor items (< 4% by weight) when salmon are present than when salmon are absent. It appears that the cutthroat foraging behavior is overall more focused on salmon eggs and fry when salmon are present, and less on other prey.

Coastal Cutthroat Diet Variability by Length

Cutthroat diet items constituting 4% or more by weight, varied by fish length during the months chum salmon were present and absent (Figures 5 and 6). The two groups of larger (301-500 mm) cutthroat, had consumed all salmon eggs and most chum fry, and had also consumed most of the non-salmon fish. The smaller (195-300 mm) cutthroat had consumed a few chum fry and non-salmon fish, while a large proportion of their diet consisted of invertebrates, such as polychaetes, amphipods and isopods.

Polychaetes (segmented worms) frequently occur in the diets of all cutthroat when salmon eggs and fry are not present (Figure 6). Non-salmonid fish and invertebrates also occur more frequently in cutthroat diet. Small samples limit inferences about relationships between prey size and cutthroat length, or seasonal diet shifts. Pacific sand lance, Pacific herring, arrow goby and shiner perch occur in larger cutthroat and clam necks occur in the smaller cutthroat.

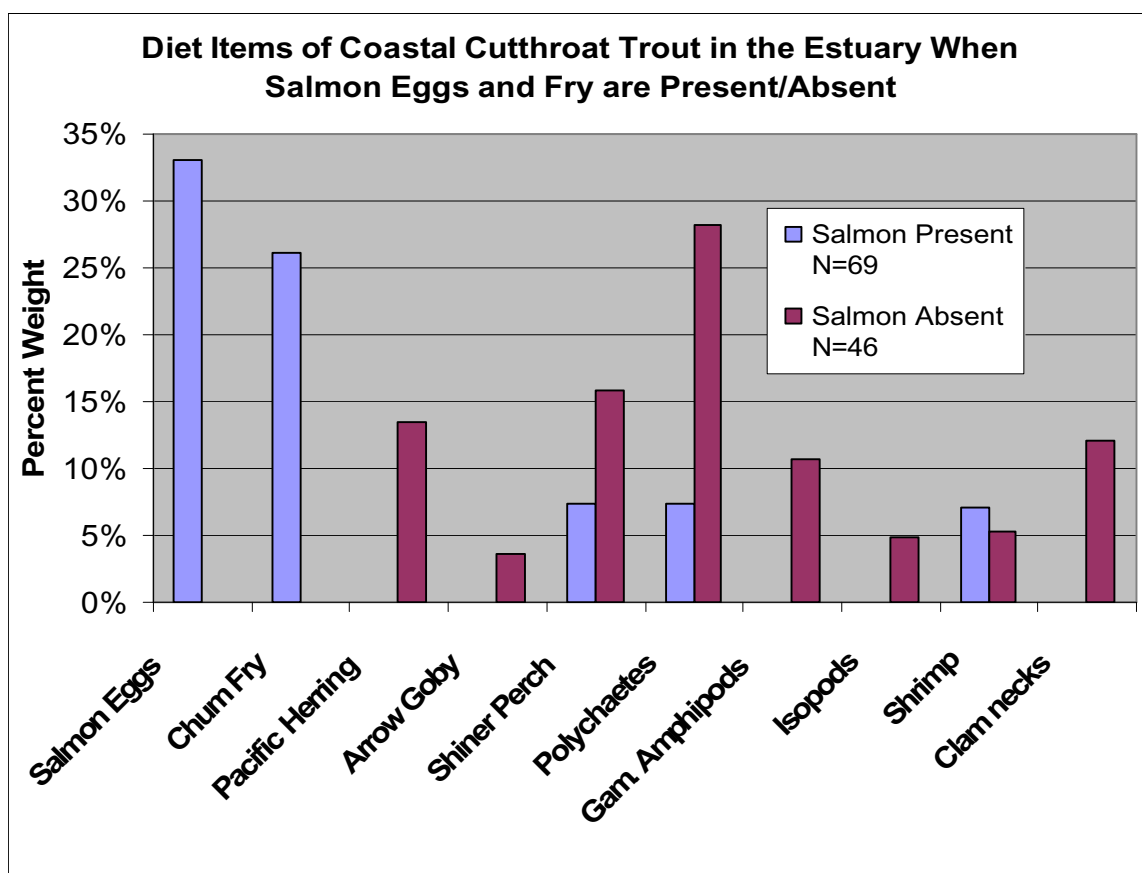


Figure 4. Diet Items 4% or more, by weight, of coastal cutthroat trout in the nearshore when salmon eggs and fry are present / absent, (N=115).

Summary of Results

1. Salmon eggs and chum salmon fry frequently occurred (46% by weight) in the diet of 115 coastal cutthroat in South Puget Sound.
2. Cutthroat over 300 mm consumed most of the salmon eggs, chum salmon fry and non-salmon fish. Cutthroat less than 300 mm consumed invertebrates, few chum salmon fry and non-salmon fish, and no salmon eggs. The length-diet relationship is not highly significant (Chi square $P(0.11)$ with 2 df).
3. Apparently cutthroat consume salmon eggs and chum salmon fry when they are available in the estuary and shift to alternative food items when they are absent. This occurs when numerous other prey items available. Sample sizes were too small for diet comparisons of coastal cutthroat length by salmon presence/absence.

Discussion

Coastal cutthroat are consistent, seasonal predators on the eggs and fry of salmon when the opportunity arises (Trotter 1989; Sumner 1972; Armstrong 1971; Dimick and Mote 1934; Giger 1972a; Loch and Miller 1988). This sample of 115 nearshore cutthroat had ingested 46% by overall weight, of salmon eggs and chum salmon fry, and shifted their diet to non-salmon fish, polychaetes and other invertebrates when salmon were not present as a food source.

The relative importance of salmon eggs and fry in the cutthroat diet is illustrated by the weight of shiner perch, which totaled five (5) specimens, four (7% of diet) when salmon were present and one (16% of diet) when salmon were absent. Polychaetes numbered 32 (7% of diet) when salmon were present, and 20 (28% of diet) when salmon were absent. Salmon eggs and fry occur more frequently in the stomachs of larger, more mobile cutthroat. Clam necks (721) occurred frequently, mostly in two cutthroat less than 300 mm in length.

Evolution of life history traits by Pacific salmon is respective to success in species run timing and other behavioral traits (Groot and Margolis 1991). Cutthroat feeding habits, as documented in this study, demonstrate recognized, successful life history adaptations that are synchronized with two periods of high energy demands, shortly before and soon after

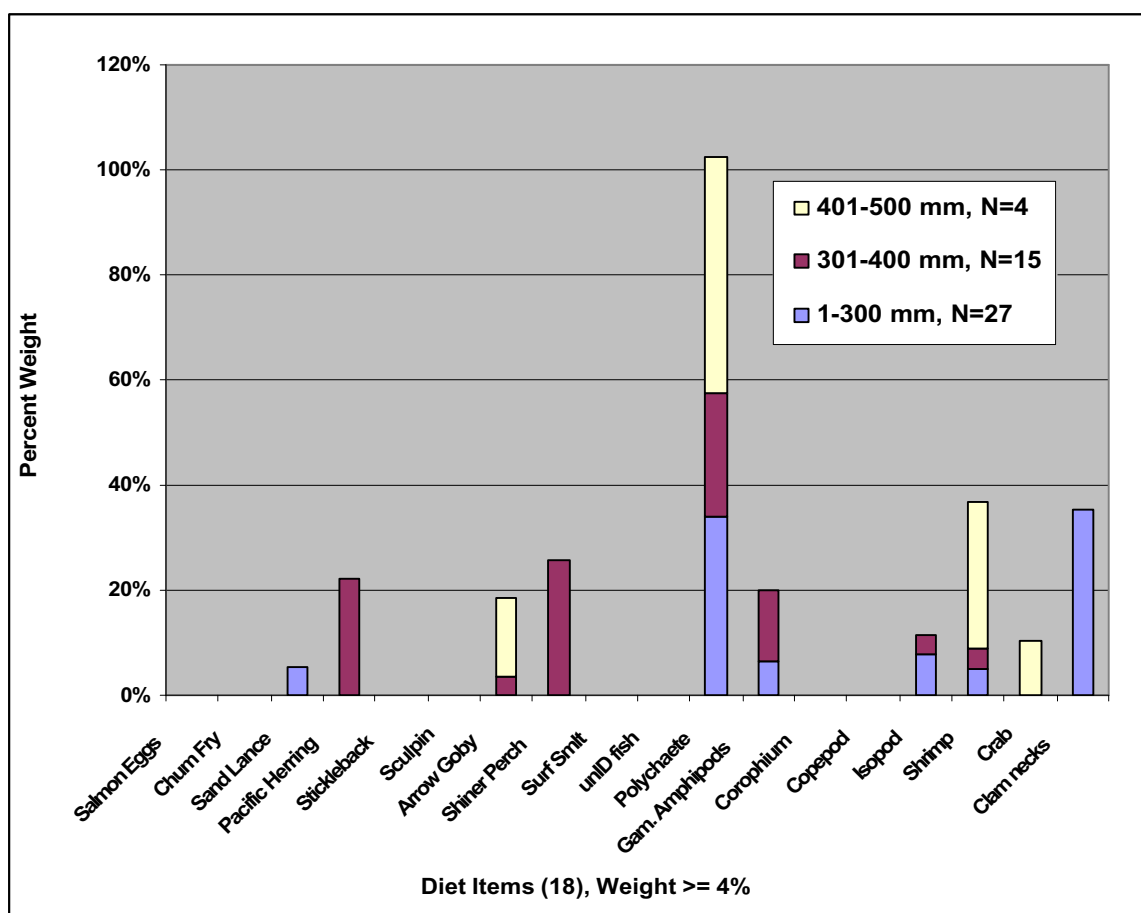


Figure 5. Diet items related to cutthroat length for months when salmon eggs and fry are present (October – January, March and April)

spawning (Johnston 1982). Cutthroat are positioned to feed heavily on salmon eggs shortly before their spawning run in January-March, and to feed on chum (or pink, where available) salmon fry after spawning, probably the end result of successful evolution in the presence of other Pacific salmon (Armstrong 1971; Johnston 1982; Northcote 1997). Increased cutthroat fitness and fecundity probably results from this successful adaptation to the movements of other salmon (Northcote 1997). The ecological significance of this interspecies interaction has been recognized by salmon and nearshore scientists (Cederholm et al. 2001; Cederholm 1998; Simenstad et al. 1982).

Availability or abundance of prey can be episodic, seasonal, or inter-annual events (Trotter 1989). Cutthroat feeding was observed on chum fry close to shorelines and frequently on or at the surface. During intensive cutthroat feeding, specific biological and physical conditions were observed that concentrated the chum fry. Biologically, they schooled and fed within 2-3 m of shorelines; physically, strong currents swept the fry along shorelines into deeper water where the cutthroat attacked them. Two of ten cutthroat captured with chum fry in their stomachs died because of deeply ingested artificial flies caused by aggressive feeding.

A large cutthroat (430 mm) contained 57 relatively undigested chum fry, one alive, unmarked and swimming freely in the collection bowl after lavage from the cutthroat stomach. Smaller cutthroat had fewer, more digested chum fry in their stomachs than larger cutthroat. This suggests different feeding behaviors for larger cutthroat, based on size, mobility, speed or ranging behavior, as has been observed in lake populations (Beauchamp et al. 1992; Cartwright et al. 1998; Nowak 2002). Larger cutthroat were observed more aggressively and more frequently feeding in the best positions for capturing chum fry.

Comparison of the stomach contents of 28 coastal cutthroat captured by fyke net, gill net and angling (Armstrong 1971), and a second sample of 326 coastal cutthroat taken from lakes and streams by nets and angling (Dimick and Mote 1934), found no differences in the amount or kind of prey items in their stomachs. Angling methods were assumed a more

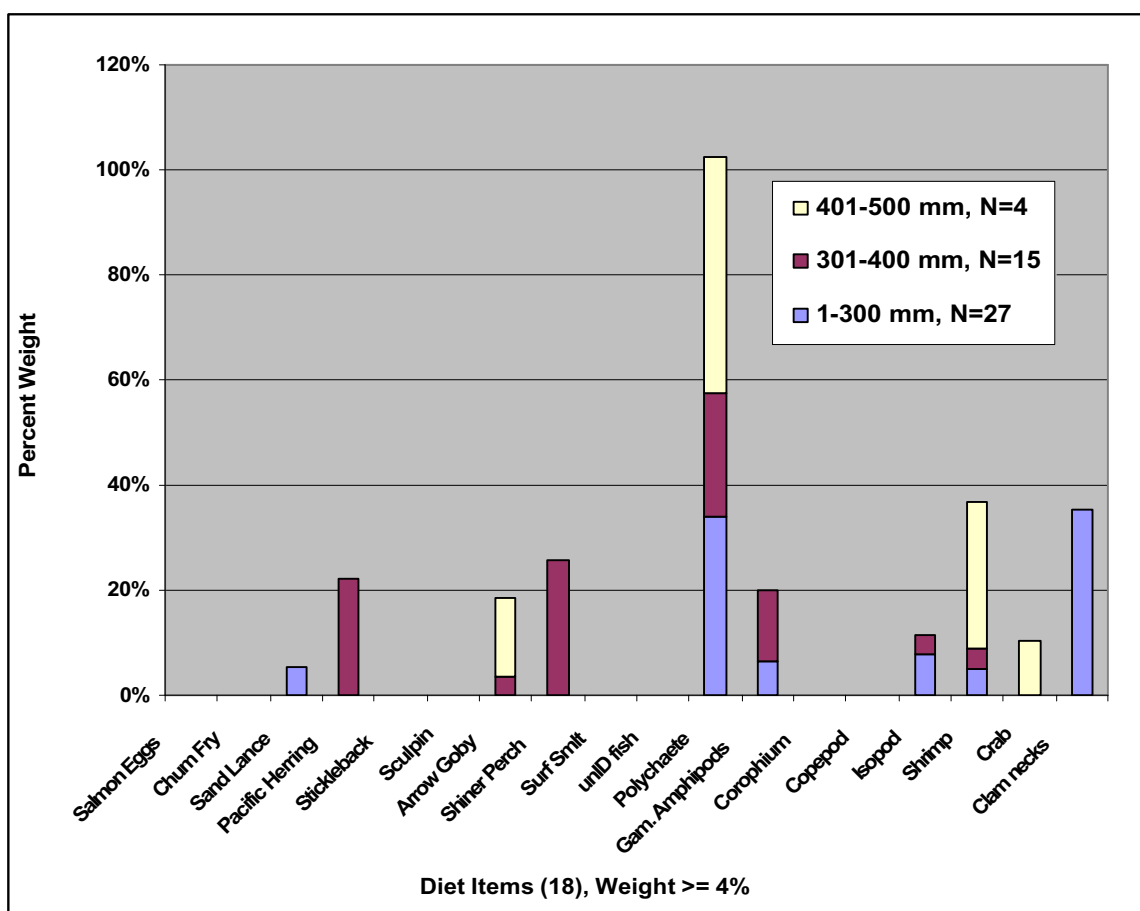


Figure 6. Diet items related to cutthroat length for months when salmon eggs and fry are not present (February, and May – September).

effective sampling tool than beach seining, based on the review of previous samples from South Puget Sound. Single, barbless-hook artificial flies (salmon fry and amphipod patterns) were used to minimize cutthroat injury, but possibly small metallic spinners and lures would have also been effective.

Recently salmon carcasses were identified as an important source of nutrition for many forms of terrestrial and aquatic life (Cederholm, 2001; Bilby et al. 1998). In a large river system, Michael Jr. (1995) found a direct relationship between mass-spawning pink salmon and the production of coho salmon of the previous brood year. This study indicated that pink salmon carcasses were a major food source for the overwintering juvenile coho. Schmidt et al. (1998) suggest a positive-feedback mechanism directly related to the size of the spawning escapement as the only consistent explanation of long- and short-term population trends for sockeye salmon. This feedback mechanism partially explains the population fluctuations of estuary dwelling cutthroat, as well as, perhaps, other salmon species. Declines of spawning salmon reduce carcass nutrient availability, and may limit freshwater and estuarine production of cutthroat (Johnson et al. 1999, Thompson 2001). The number of cutthroat feeding on salmon eggs and fry in estuaries would probably increase with an increase in the number of salmon allowed to spawn and die in streams (Reimchen 1984).

Ecologically based escapement is a new concept in salmon harvest management that is in direct competition with the existing paradigm of maximum sustained yield (MSY) (Cederholm et al. 2001). Maximum sustained yield has failed to account for the long-term importance of salmon carcass nutrients as a driving force in salmon productivity (Schmidt et al. 1998). Prior to 1860, abundant salmon runs provided substantial nutritive advantages for estuary dwelling cutthroat, as they did for a large host of other terrestrial and aquatic species (Cederholm et al. 2001). It is estimated that today less than 10% of historic nutrients once deposited upstream by migrating salmon reach rivers Gresh et al. 2000). This has likely negatively affected the productivity of streams supporting populations of cutthroat (Michael Jr. 1995). In this regard, the declines of coastal cutthroat trout may mirror the declines of other Pacific salmon species.

In Totten Inlet (study area), Thompson (2001) found that spawning salmon and spawned-out carcasses significantly increased estuary concentrations of ammonium. Thompson (2001) suggested that ammonium from salmon was important for production of harpacticoid copepods, an important food source of estuary rearing chum salmon fry (Simenstad et al. 1981; Wissmar and Simenstad 1988). If these chemical nutritive links between adult chum salmon and their subsequent fry are true, then cutthroat survival is likely ecologically linked to chum salmon by cutthroat reliance on migrating chum salmon fry.

Cutthroat predation on ESA-listed salmon species in Puget Sound could be considered a detriment, working against management actions to increase cutthroat abundance. For sockeye and pink salmon fry, coastal cutthroat have already been well established as successful lake-based predators (Beauchamp et al. 1982; Cartwright et al. 1998; Nowak 2002). The nutritive chain supporting cutthroat and other salmon species, from freshwater to estuary, would probably benefit from increases of naturally spawning Pacific salmon (Michael Jr. 1998).

In the past 150 years, Washington's estuary habitat losses have been caused by the cumulative effects of agriculture, logging, mining, dams, grazing, urbanization, industry, exotic species and aquaculture (Simenstad and Thom 1992; Emmett et al. 1991; Johnson et al. 1999). Overall area loss of Washington coastal tidal wetlands is 42%, of Puget Sound estuaries is 71%, and of Puget Sound eelgrass is 70% (Simenstad and Thom 1992). In Puget Sound the Duwamish River and Commencement Bay estuaries are 99-100% degraded, and Nisqually River estuary has lost 55% of its area (Johnson et al. 1999; Bortelson et al. 1980).

In Thurston County (study area), shoreline armoring increased by over 100% from 1977 to 1993, impacting riparian vegetation, upper beach areas, and wave energy and sediment movement along shorelines (Johnson et al. 1999). Changes in fluvial geomorphology can change the biological characteristics of estuary food webs by clearcut logging, for example, which increases sediment delivery, and by modifications to river hydrodynamics which decreases seasonal water and sediment pulses ((Simenstad et al. 2000; Cederholm et al. 1981; Simenstad et al. 1997). Anthropogenic changes in water flows, quality, or timing, can negatively effect primary and secondary estuarine productivity, can increase stress on migrating or feeding salmon, and cause low flow obstructions to smolt migrations (Simenstad et al. 2000; Johnson et al. 1999). Substantial declines in woody debris in estuaries also reduces coastal cutthroat populations through temperature increases and refuge site losses (Johnson et al. 1999; Maser and Sedell 1994).

Coastal cutthroat could indicate fresh and saltwater ecosystem function,. following Behnke's (1987) comment about cutthroat being the "canary in the mine," because they are the first species to disappear after environmental degradation. However, degraded urban stream habitats may shift beyond the adaptive capabilities of some salmon species, reducing diversity, and support cutthroat better than coho (Lucchetti and Fuerstenberg 1993; Ludwa et al. 1997). Lucchetti (personal communication, 2002) found that a coho:cutthroat ratio of 4:1 may indicate a healthy, unurbanized system, and that degraded low gradient streams with adequate temperatures and reduced channel complexity may behave more like headwater systems, supporting less coho and more cutthroat.

In urbanized nearshore areas, coastal cutthroat are vulnerable to over-fishing by recreational anglers because they are relatively accessible and easy to catch (Emmett et al. 1991; Trotter 1997; Raymond 1996). In Washington, recreational fishing was "...*probably a significant source of mortality in the past...*," but recent restrictions have resulted in some local population increases in coastal cutthroat (Johnson et al. 1999).

In South Puget Sound, gear restrictions and catch-and-release regulations for recreational cutthroat fishing have been in place for about ten years, resulting in some apparent population gains, though no definitive population estimates exist. Regulations alone are unlikely to produce significant cutthroat population increases because of their seasonal reliance on other Pacific salmon for critical nutrition, and a lack of ecosystem-based salmon escapement levels.

This report ends with a question: What are the trophic dynamics and food webs leading to coastal cutthroat? A comparison of the seasonal distribution and growth patterns of coastal cutthroat, including their predators and prey in various estuarine habitat areas, would yield broad functional knowledge of the terrestrial-marine ecotone. Perhaps this would allow managers to begin to understand the coastal cutthroat and it's place in the dynamic estuarine mosaic.

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